A Study of an Operator Assistant for Virtual Space

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Abstract

This paper describes and evaluates a method to assist an operator to place an object on a surface in a virtual environment without any force feed-back tool. The method used is to apply an attractive power to two faces that are likely to be attached. The system checks the distance of these faces and assists the operator by attaching two faces whose distance is less than a certain threshold. The real time calculation is achieved by limiting the number of faces that can be attached. Using this interface, the operator can move an object in some predefined planes. An experiment showed that the method was effective when the operator was requested to precisely place a virtual object in a certain location.

1 Introduction

A virtual environment, which is created by computer graphics and an appropriate user interface, can be used in many applications. For example, by measuring the user's viewing position, hand position and hand shape, we can establish an object manipulation environment in virtual space where the operators can directly grasp, move or release the objects created by stereoscopic computer graphic images. In the simplest virtual space, there are not any constraint on the position of a grabbed object, it is very difficult to perform any construction task, e.g. putting two objects in contact.

To solve this problem, it is possible to add the "non-permeability" constraint by detecting collisions between any two objects. This calculation can be combined with simulated gravity [1] [2] or a force feed-back tool [3] to enable the assembly of objects. However, collision detection using edges and surfaces employed in [1] requires considerable computation time when the number of faces describing the world is high. Therefore, real time calculation was difficult. Moreover, the force feed-back tool requires complex hardware.

To achieve the effect of the contact force in the real world, we decided to use "attraction" in the virtual world. The bottom face of an object in a stable attitude is identified [4]. Furthermore, potential collisions of faces of a grabbed object are efficiently tested, and a pair of attractive faces that are likely to be put in contact is selected [5]. By using a selected pair of attractive faces, we designed an operator assistant tool in virtual space with a simple configuration.

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In this paper, we describe and evaluate a method to assist an operator to place an object on a surface in a virtual environment without any force feed-back tool. The effectiveness of this method is shown in section 4 through the experimental result, particularly when an operator is requested to precisely place a virtual object in a certain location.

2 Operator assistant for virtual space

The goal of our method is to give appropriate assistance to an operator trying to place a virtual object at a target position. In a simple implementation of a virtual environment, where objecta are permeable to each other, it is known that a simple task such as placing two cubes in contact is very difficult. However, giving all the constraints we have in the real world to the virtual world is not only difficult because of computational constraints but also not a good idea in terms of operator assistance. As the goal of the operation is to locate an object to a certain target position, the system should positively assist the operator when the system can find where the target position is.

One assumption which can apply in most virtual object manipulation is that when an operator places a face of one object very close to a face of another object, the operator is trying to put two faces in contact. By using this assumption, we propose the following method to assist an operator.

1. find two faces that are likely to be attached to each other.
2. attach the two faces and constrain the motion of the grasped object at the attached face.

Two faces are found by using the distance and direction of any two faces that are pre-defined as attracting faces. By keeping the number of attracting faces relatively small, real time calculation can easily be achieved. In many object-arranging applications, such as office planning, kitchen design, etc., the number of faces that can be placed in contact with an other face is limited. Therefore, our method is applied.

When there are many attracting faces or where every face must be checked, we have to use a more efficient method to determine which faces are likely to be brought together [5]. We have implemented this method in the virtual object manipulation system we developed. In this system, a 70-inch stereoscopic display is used to visualize the virtual world. An operator wearing stereoscopic viewing glasses and a DataGlove can handle virtual objects as they do in the real world. The Following section describes experiments we carried out using this system.

The concept of our method is shown in Figure 1. With this tool, the operator can grasp an object, move it to an "attracting plane", then if he keeps an "attracted face" of the object in a certain area near the "attracting plane," he can move the object while keeping the attracted face on the plane. In other words, all the operator needs do is control two translations and one rotation of freedom of the grasped object.

3 Determination of the system parameter

The decision to move the grabbed object to the closest object was carried out if the distance separating them was smaller than a threshold value. This threshold was determined

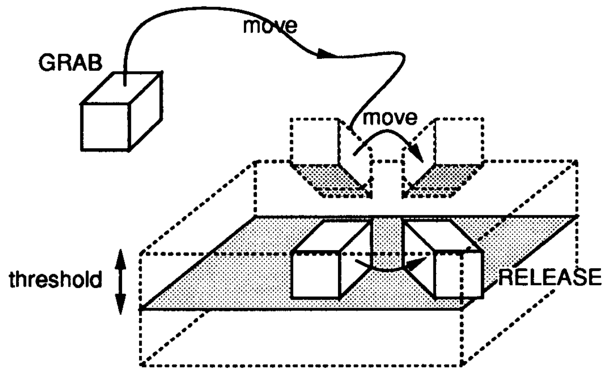


Figure 1: Concept of operator assistant

empirically through the following experiment.

3.1 Experimental method

Five persons took part in this experiment. Among them, some were very familiar with moving objects in virtual space, while some had no prior experience with this kind of manipulation. Consequently, before the experiment began, each subject was asked to grab, move and release a number of objects until they felt comfortable.

For ten decreasing threshold values (from 32cm to 0.2cm), the subject had to move three cubes with an "attracted face" on an "attracting" plane. Each trial was repeated five times. The plane was 32cm square and the cubes had a 6cm edge. The cubes were 21cm away from the plane as illustrated in Figure 2. The task was considered to be achieved for a cube if the distace between its "attracted face" and the plane was less than the threshold value. The operator was kept informed through visual feedback (the cube changed color).

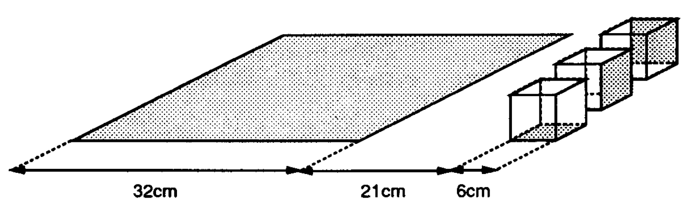


Figure 2: Experiment to determine system parameter

3.2 Results

For each person, the mean time (in five trials) required to succeed in releasing one, two and three cubes on the plane was measured. The graph has nearly the same shape for each subject (a curve decreasing quickly at the beginning, then reaching a converging line).

However, the scale is very different for each subject. This is due to the fact that people had various levels of expertise in moving objects in a virtual world. Consequently we had to normalize data before arriving at the mean. To do so, we assumed that the showtest time was nearly equal to the converging value and that the longest time was the time needed to accomplish the task without interaction, and reduced the interval to the interval $[0, 1]$ with the following formula: $x = \frac{t - t_{min}}{t_{max} - t_{min}}$. Here, $(1 - x)$ represents the gain in time for performing this task using the tool.

Figure 3 (a) shows the normalized results gathered from the five subjects. It shows that the behavior of each subject is very similar and consequently that a single threshold value could be used for all five subjects. Figure 3 (b) shows the mean curve of the five previous curves. It is used to find an appropriate threshold value.

The interaction between the attracting faces introduces a discontinuity in the movement of the object (when the computer changes the position). This discontinuity looks strange to the operator, so it is important to reduce its effect. To do so, the threshold value has to be as small as possible.

We chose a threshold that would allow the operattor a gain of 90%. This threshold is at the intersection of the mean curve and the line x=0.1, which gives the value of 2cm.

4 Evaluation of the tool

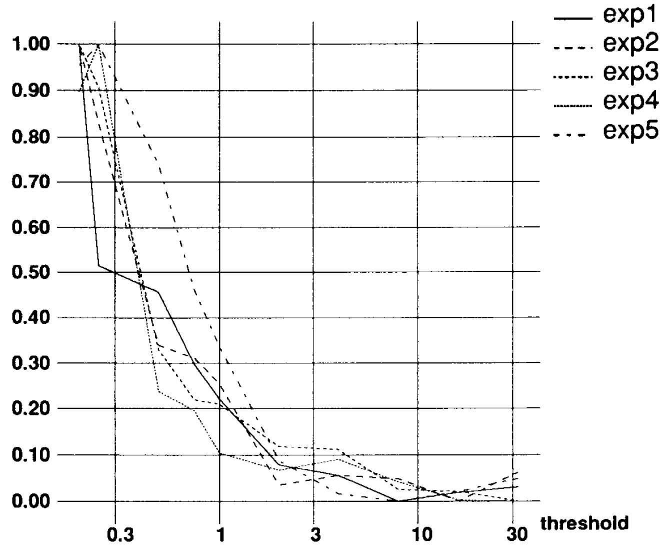
The goal of the second experiment was to determine how the interface we implemented facilitates the manipulation of objects. It calculates the gain of time made when using the interface with a threshold value of 2cm compared with a world without interaction. The task accomplished was the assembly of two cubes.

4.1 Experimental method

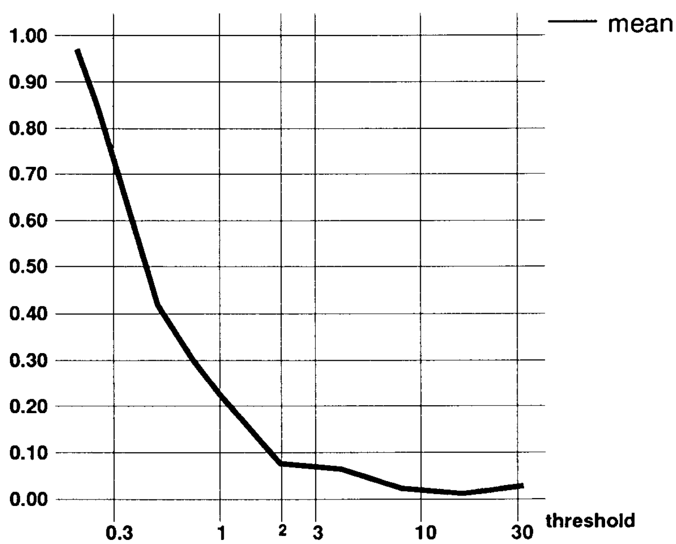
Five persons were asked to do the same experiment ten times. The goal was to move a cube containing an "attracted face" on a fixed cube containing an "attracting face" six times (three levels of difficulty two configurations, i.e. with and without interaction). The cubes were 19cm apart and had a 6cm edge as shown in Figure 4. To complete the task, the operator had to put the two interacting faces in contact with the corners of the cubes coinciding. To test the coincidence, the sum of the distances between all four corners of the "attracted face" and the closest corner of the "attracting face" was computed. The task was considered to be achieved if this sum was smaller than a given value. We called this value the "difficulty" of the task (the lower value corresponds to the harder task). The operator received the same visual feed-back as in the previous experiment (color change of the cube) when the task was achieved.

4.2 Results

For each person, the mean time (in ten trials) required to put the cubes together was measured. The scale is very different for each operator because their ability to move objects in the virtual space was very different. The biggest difference appeared for the most difficult task, where it was important to keep the hand steady in free space. Nevertheless, operator behavior was very similar. The task was always done quicker with interaction and the time



(a) 5 persons (normalized data)



(b) 5 persons (mean normalized data)

Figure 3: Eperimental results for the 5 operators to determine the system parameter

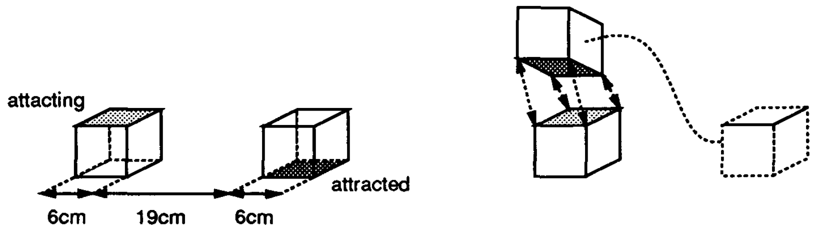


Figure 4: Experiment for evaluation of the tool

saved increases with the difficulty of the task. Figure 5 shows the results of the experiment. In this figure, mean and standard deviation of the time to achieve the task are shown for both with and without interactions.

As we had a common behavior but different scales, we decided to normalize the data by using the fraction : $x = \frac{t_{with}}{t_{without}}$. This fraction is an indicator to evaluate the effectiveness of the interactions given the following task: move one cube on to another with a certain accuracy. We calculated the mean and standard deviation of these indicators for the five subjects. The results are shown in Figure 6. The effectiveness of the interaction grows with the difficulty of the task. For the most difficult task, the time fell by nearly half using this method.

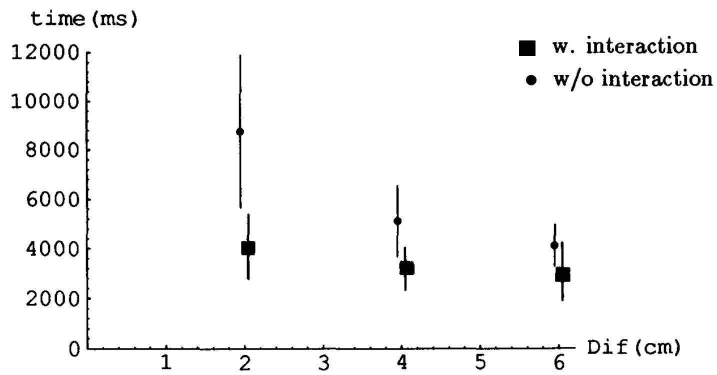


Figure 5: Mean and standard deviation of the time required to achieve the task

5 Conclusion

In a virtual world, giving an attractive power to the faces of a grabbed object, we built a new interface, which facilitates the precise placement of one object on another. The interface,

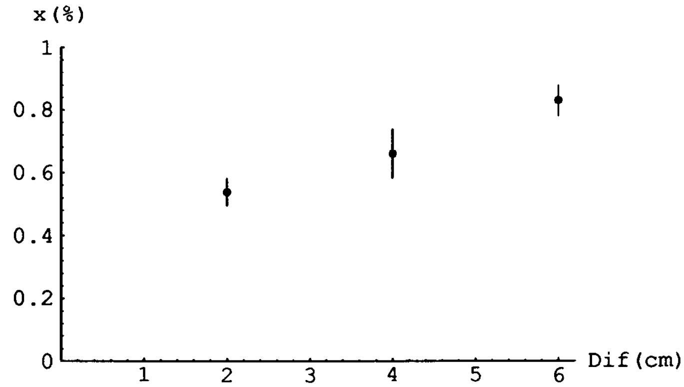


Figure 6: Normalized mean and standard deviation of the indicator x

using "attracted faces" and "attracting faces" operates in real time.

An experiment was conducted to determine the threshold value at which the computer interacts with the user for the placement of the object. In our application, the chosen threshold is 2cm.

A second experiment showed that the effectiveness of the interface increases with the difficulty of the task. The time saved using the interface could be as much as 50%.

The current tool choses one target object, but for future work, a multiple choice should be available to enable a manipulator to release an object in a corner and not only on a plane.

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